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STUDY PROJECT

USING TODAY'S TECHNOLOGY TO IMPROVE MOBILE C4I FOR THE OPERATIONAL COMMANDER

BY

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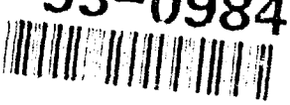

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19. ABSTRACT (Continue on reverse if necessary and identify by block number) The rapid development of communications and computer technology in the commercial market provides the Army with a unique opportunity to relook the way we provide command, control, communications, computers and intelligence (C4I) on the battlefield. Desert Shield/Storm experiences demonstrated the capability and reliability of off-the-shelf equipment and enhancements in battlefield awareness provided by new military systems. However, after action reviews also revealed significant problems for operational commanders during Desert Shield/Desert Storm with command and control "on the move." As a result, the Chairman, Joint Chiefs of Staff approved a program called "C4I for the Warrior." The thrust of the program is to provide a seamless C4I architecture to support the warfighter. The effort is phased over three periods; Quick Fix Phase (POM years), Mid-Term Phase (POM plus 10), and Objective Phase (beyond Mid-Term period). This study looks a leveraging current technology and new military systems in the Quick Fix and Mid-Term phases to provide a communications and computer workstation for an operational commander's command and control vehicle (C2V). Application of current systems to meet the

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commander's battlefield information needs are compared to new systems achieved through modifications and off-the-shelf procurements. The recommended solution integrates the Global Positioning System (GPS) with combat net radios (CNR), common hardware/software (CHS) computers, and Mobile Subscriber Equipment (MSE) to provide an integrated picture of the battlefield. Additionally, it capitalizes on CD ROM and newly-available, multifunctional printer technologies to provide a complete information processing and distribution system. The study concludes that adoption of recommended modifications, program changes, and procurements will solve many of the C4I problems encountered at the operational level during Desert Shield/Desert Storm.

USAWC MILITARY STUDIES PROGRAM PAPER

USING TODAY'S TECHNOLOGY TO IMPROVE MOBILE C4I FOR THE OPERATIONAL COMMANDER

AN INDIVIDUAL STUDY PROJECT

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ABSTRACT

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The rapid development of communications and computer technology in the commercial market provides the Army with a unique opportunity to relook the way we provide command, control, communications, computers, and intelligence (C4I) on the battlefield. Desert Shield/Desert Storm experiences demonstrated the capability and reliability of off-the-shelf equipment and enhancements in battlefield awareness provided by new military systems. However, after action reviews also revealed significant problems for operational commanders during Desert Shield/Desert Storm with command and control "on the move". As a result, the Chairman, Joint Chiefs of Staff approved a program called "C4I for the Warrior". The thrust of the program is to provide a seamless C4I architecture to support the warfighter. The effort is phased over three periods; Quick Fix Phase (POM years), Mid-Term Phase (POM plus 10), and Objective Phase (beyond Mid-Term period). This study looks a leveraging current technology and new military systems in the Quick Fix and Mid-Term phases to provide a communications and computer workstation for an operational commander's command and control vehicle (C2V). Application of current systems to meet the commander's battlefield information needs are compared to new systems achieved through modifications and off-the-shelf procurements. The recommended solution integrates the Global Positioning System (GPS) with combat net radios (CNR), common hardware/software (CHS) computers, and Mobile Subscriber Equipment (MSE) to provide an integrated picture of the battlefield. Additionally, it capitalizes on CD ROM and newly-available, multifunctional printer technologies to provide a complete information processing and distribution system. The study concludes that adoption of recommended modifications, program changes, and procurements will solve many of the C4I problems encountered at the operational level during Desert Shield/Desert Storm.

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INTRODUCTION

Desert Shield/Desert Storm was certainly an outstanding military victory for the United States and our coalition partners. The lessons learned will surely be the subject of studies and analysis both within and outside the Department of Defense for years to come. However, even a successful campaign illuminates shortcomings or deficiencies in our policies, doctrine, procedures, and equipment. Documentation of these problems range from the rather bland and non-specific to the acerbic. For example, the Department of Defense (DoD), Conduct of the Persian Gulf War, Final Report to the Congress, contained the statement,

> Providing reliable and continuous command, control and communications with a rapidly moving force across vast distances during the ground war raised a whole new set of *challenges* (emphasis added).[1]

While the officer in charge (OIC) of the VII Corps tactical command post (TAC) reported,

> ...the communications system within the Corps was nightmarish. Beyond the LD/LC, FM radio and tactical satellite (TACSAT) systems were the only means available common to all Corps major subordinate units. ...degradations obviously impacted on the TAC's ability to synchronize the close battle,...[2]

The preceding quotes, especially the second, highlight communications shortcomings that are the main focus of this study and which were, along with dissemination of tactical intelligence, two of the major problems identified during Desert Shield/Desert Storm. Finding communications and intelligence together is not surprising and certainly nothing new since they

both relate rather directly to obtaining, processing, and distributing information. In fact, on today's battlefield they are so interdependent that they have customarily been lumped together as command, control, communications and intelligence (C3I). With the rapid proliferation of digital stand-alone and weapons embedded systems this has been expanded today to include computers and become command, control, communications, computers and intelligence (C4I). Putting all of these elements together in an acronym has proven to be easier, however, than putting them together in the Department of Defense and on the battlefield. With Desert Shield/Desert Storm as the catalyst, a major corporate look at coming to grips with the problem has been instituted by the Chairman, Joint Chiefs of Staff (CJCS) as the "C4I for the Warrior" program under the J-6 of the Joint Staff.

C4I FOR THE WARRIOR

Looking into the C4I for the Warrior program and understanding what it may mean in the future for the Department of Defense and the Army is best begun by reviewing its description by General Colin Powell, CJCS.

> The C4I for the Warrior concept will give the battlefield commander access to all information needed to win in war and will provide the information when, where, and how the commander wants it.
>
> At the height of the Persian Gulf conflict, the automated message information network passed nearly 2 million packets of information per day through gateways in the Southwest Asia theater of operations. Efficient management of information increased the pace of combat operations, improved the decisionmaking process, and synchronized various combat capabilities. The

> technology developed to support these networks proved to be a vital margin that saved lives and helped achieve victory.
>
> Many challenges still must be faced. The downsizing of military forces and the shrinking defense budget have resulted in increased reliance on C4I interoperability. The C4I for the Warrior concept starts with the Warrior's requirements and provides a roadmap to reach the objective of a seamless,secure, interoperable global C4I network for the Warrior.
>
> The time is ripe to set a course to resolve our C4I interoperability issues. C4I for the Warrior provides the vision and the roadmap for present and future C4I support of our joint warfighting forces.[3]

The objective vision is a widely distributed network to which the warrior "plugs in" through the tactical command and control system defined by the warrior. The roadmap is time-phased over three phases; the Quick Fix Phase (POM Years), the Mid-Term Phase (POM Plus 10), and the Objective Phase (Beyond the Mid-Term Period). The Quick Fix Phase objective is to take actions now that will result in near-term interoperability improvements primarily through translators and joint standards. In the Mid-Term interoperability will be achieved through modular building blocks, designed-in interoperability for new systems, and establishment of a joint wide-area network. The open-ended Objective Phase will be shaped by emerging technologies but the end state is assimilation of technologies and common interfaces into a global C4I network of fused information.[4] To see how this impacts on the warrior and warfighting we must relate the individual components of C4I to that battlefield. Command and control, though not synonymous, will be considered first.

COMMAND AND CONTROL

Command means many things to many people. Control, likewise, is defined from various perspectives and putting them together as "command and control" (C2) certainly doesn't help ease the definition problem. Martin Van Creveld in his renowned book, Command in War, described a "process of command" that a U. S. Army War College student paraphrased as,

> the gathering, storing, and processing of information; estimating the situation; developing alternate courses of action; decision making; detailed planning; drafting and transmitting orders; executing the plan; and, monitoring.[5]

GEN(Ret) Frederick J. Kroesen, former U. S. Army Europe (USAEUR) commander, said,

> Command and control entails the capability of a commander to do three things at all times: command military operations of his subordinate forces, direct the support operations that are essential to the conduct of those operations, and determine when and how to ask for help.[6]

This concept was presented in the context of operating from a command post that shared the control function by ensuring the commander was kept abreast of the situation and ensured that subordinates were provided the means to accomplish the mission. Together they accomplished the overriding mission to synchronize all activities that led to successful military operations.[7]

LTG Shoffner, Commanding General, U. S. Army Combined Arms Command, had the view that "command" was exclusively the purview of the commander and "control" was staff's business. To him:

> Command is the art of visualizing a future state; formulating concepts of operations; assigning missions; decision making; prioritizing & risk assessment; seeing, hearing & understanding; selecting critical time & place; anticipating change; and leading, guiding & motivating the organization.
>
> Control is the science of defining limits; computing requirements; allocating means; describing interfaces; monitoring status; identifying variance; acquiring & applying means to accomplish cdr's intent; developing specific instructions from general guidance; correcting deviation from guidance; measuring, reporting and analyzing performance; and projecting change.[8]

The common thread to all of these views is that command and control relates information gathering, analyzing, processing, and dissemination to provide the situational awareness necessary to successfully accomplish a military mission. Without information flow command and control is impotent. How then might we combine the next two elements of C4I, communications and computers, to provide the warrior a means to handle information and win the information war?

COMMUNICATIONS AND COMPUTERS, A SOLUTION?

Today's rapid development of technology in communications and computers in the commercial market may provide the Army with a unique opportunity to relook the way we provide C4I in the near-term on the battlefield. In addition, rapidly shrinking budgets and manpower dictate that we find new, cheaper, and more effective ways to do our business. The demonstrated capability and reliability of many commercial off-the-shelf items in the harsh field environment of Desert Shield/Desert Storm[9] should

lead us to strongly encourage their use in any future command and control system. For example, the Vice-President of Rockwell International reflecting on the fact that more than 85 percent of the global positioning system (GPS) receivers used were commercial models said,

> This highlights the application of dual-use technology and the increasing capability of the commercial sector to provide equipment for the battlefield, which, though not conforming to military specifications, has acceptable reliability and performance.[10]

Computers and digital devices are ubiquitous throughout the Army today and we must harness the power of these devices to provide commanders with the information and decision aids to win on the battlefield. Moreover, many new military systems are being fielded, or have been fielded, that provide tremendous new capabilities. The equipment is available; putting it all together in an integrated package quickly and with minimal development costs is the challenge.

This paper will examine the requirements for a communications and computer suite to support an operational commander in a mobile tactical operations center or a command and control vehicle (C2V) within the context of the C4I for the Warrior program primarily in the Quick Fix and Mid-Term phases. This focus was chosen because one of the major communications problems revealed in Desert Shield/Desert Storm was identified in an after action review by the Army Science Board as command and

control "on the move".[11] The general approach is described below.

Generic information requirements are identified and current systems used to provide, process, record, and disseminate this information discussed. Capabilities of current military and civilian communications, automation, and digital devices that can be leveraged to accomplish these tasks more efficiently and lessons learned on their performance in Desert Shield/Desert Storm are presented. A proposal for the integration of these systems, and recommended or required equipment and/or software modifications, program changes, or new developments necessary to design a more effective communications and computer equipment suite are then highlighted. We begin by defining what information a commander needs to "command and control" on the battlefield.

BATTLEFIELD INFORMATION REQUIREMENTS

The battlefield commander needs various types of information to "see" the battlefield and command. He also needs to communicate with higher, lateral, and lower organizations. The better the information and more rapid the communications the more likely the commander will be able to defeat the enemy and protect his own forces. To some extent the information required by a commander depends upon the type of unit he commands and the doctrinal considerations of mission, enemy, troops, terrain, and

time (METT-T). However, for brevity and simplicity some generic "types" of information needed by any commander can be grouped as:

(a) **Position/Location** - Your own location, the locations of friendly units and support facilities, and the locations of enemy units. Locations of barriers, obstacles, contamination, main supply routes, supply bases, water points, ammunition dumps, fuel depots, etc. are also important. For the purposes of this paper this category also includes topographical information.

(b) **Status** - Current and projected status of personnel, equipment, weapons systems, and supplies. Equipment status is normally tracked by battlefield operating systems and supplies by class. The status must include friendly, supporting, and supported units as well as your own and adjacent units.

(c) **Mission/Situation** - The mission of the unit and associated timelines. The situation normally includes the friendly and enemy order-of-battle. The mission may also specify a doctrinal scheme of maneuver and battlefield control measures such as coordinating points, crossing points, etc.

(d) **Equipment Capabilities/Requirements** - The technical specifications of unit and supporting equipment; weapon ranges, supply consumption rates, keylists, etc.

In order to obtain, process, record, and distribute the information discussed above the commander at the operational level would normally have communications and support equipment in a mobile vehicle or command post such as:

(a) **Combat Net Radio (CNR)** - A military standard radio that would doctrinally operate with a communications security (COMSEC) device to provide secure voice communications. These would normally include FM radios of either the older AN/VRC-12 family or the newer, frequency hopping, Single Channel Ground and Airborne Radio System (SINCGARS); and, in limited cases, the UHF single channel tactical satellite (TACSAT) radio. The exact quantity and specific type of radios are determined by equipment authorizations and the configuration desired by the commander. The nets at various echelons in which the commander or command post must operate are another consideration. All the radios require ancillary support such as technical manuals, keylists and/or electronic keying devices for the COMSEC equipment, and communications-electronics operating instructions (CEOIs).

(b) **Field telephone** - From a fixed location, like the corps main and rear tactical operations centers (TOCs), the operational commander will most likely have a Mobile Subscriber Equipment (MSE) field telephone connected by wire to the tactical corps and joint wide-area switching systems that link to other networks to provide world-wide communications connectivity. In addition, a secure STU-III telephone would also likely be available to the commander and command group. From fixed locations this could be used to interface with commercial or host nation telephone systems for secure voice or data transmissions.

MSE is the newest common user telephone system being fielded to the total Army, including reserve components, that provides

automatic routing of calls to the desired number anywhere within the network to users of the Army tactical command and control system (ATCCS). The system interfaces with other services, joint, DoD, and commercial systems to provide world-wide connectivity to the operational commander. MSE was designed as a voice system and, therefore, has limited data capability.[12]

When MSE is fully fielded, commanders down to battalion level will also have a Mobile Subscriber Radio Terminal (MSRT) that will provide access into the MSE switching system through a vehicle-mounted radio unit. The MSRT consists of two main components: the receiver/transmitter and a built-in cryptographic system called the KY-68 Digital Subscriber Voice Terminal (DSVT) that provides end-to-end encryption of a call.[13]

(c) **Computers** - Many commanders today have desktop and laptop computers that are routinely used in a field environment. Most are commercial and there is no standard configuration nor software. However, most systems consist of a computer [with a hard drive, floppy drive(s), and sometimes a modem], a keyboard [and sometimes a mouse], and a printer. The proliferation of unique computer hardware and software has significant impacts on interoperability and controls have been established within DoD to address this problem. Initial interoperability is being sought through establishment of standards and protocols under the direction of the Defense Information Systems Agency (DISA) within the DoD Corporate Information Management (CIM) initiative.[14] Migration to total interoperability of hardware and software is

also supported by the Army as executive agent for the common hardware/software (CHS) program. One computer system, the military standard Maneuver Control System (MCS), has been under development for some time and is currently undergoing limited fielding.

MCS is an integrated network of computers designed to link over the MSE system to provide commanders at the corps, division, and brigade level an information management system. The initial system supports five databases: friendly forces; enemy forces; control measures; obstacle barriers; and Nuclear, Biological and Chemical (NBC) data. Information can be displayed in the form of charts, reports, maps, or spreadsheets and transmitted to a maximum of 35 preprogrammed addressees. The initial system is based on a proprietary computer hardware and software system but is migrating to the open architecture of the common hardware/software (CHS) system. Advances incorporated and tested during Desert Shield/Desert Storm included an electronic map background capability, a commercial autodial feature, interface with MSE and SINCGARS, and experimental use of CHS equipment.[15]

MCS is a move in the right direction toward handling the information needs of the operational commander. However, it has significant shortcomings. Specifically, the hardware and software are outdated and proprietary (therefore a closed architecture system), the system is too heavy and bulky, and the system functionality is limited.

(d) **Global Positioning System** - The Global Positioning System (GPS) [also known as NAVSTAR] is a satellite based, radio navigation system that provides precise, world-wide, three dimensional position, velocity,and timing data.[16] Users obtain the data through a stand-alone, receive-only device that automatically receives information from multiple satellites then computes and displays position information in user-selectable coordinate systems. Though currently in limited fielding GPS was widely used in Desert Shield/Desert Storm. Performance results are discussed in a later section.

(e) **Maps** - Once the area of operations is known the commander must obtain, store, and distribute maps. This is no trivial task in a rapidly moving, deep battle or in an environment where the precise area of operations is unknown. The inventory of maps that must be maintained is formidable and their transport and distribution is a major logistical concern. However, maps are absolutely essential for planning and conducting tactical operations. Today there are few units that have access to anything other than the standard paper maps. The other instrument essential for use of these maps is the lensatic compass which is dated but has proven its reliability and utility.

(f) **Manuals, SOPs, etc.** - Equipment technical manuals, field manuals, unit standard operating procedures (SOPs), "battle books", keylists, signal operating instructions (SOIs), and assorted other reference books and documents are carried to the

battle by commanders and staffs. These are indispensable for the conduct of operations but add a transportation, storage, and distribution problem similar to that of maps.

How then does the commander use the communications and support equipment he now has to address his information requirements? Additionally, what can we learn from the Desert Shield/Desert Storm operation about the effectiveness of current systems and the potential of future systems that were rushed to the field for the ultimate "operational test"?

MEETING THE NEED, C4I TODAY

All commanders and staffs obtain, process, and display information to support decisions on the battlefield in the manner that best suits the style and preferences of the commander or staff chief. The specifics differ but the approaches are somewhat constrained by current technology, the specific equipment authorized and fielded to the particular headquarters, doctrine, and traditional ways of presenting data. The one central theme is that communications are absolutely critical, regardless of service. This was aptly demonstrated during Desert Shield/Desert Storm. A reporter traveling with LTG Boomer, commander of the 1st Marine Expeditionary Force (I MEF) and the senior marine in theater wrote,

> Boomer directed the assault into Kuwait from a perch atop a mobile communications vehicle stuffed with radios. Life was a sequence of stop-and-start desert travels as the headquarters rolled north toward Kuwait City. The general spent almost every waking moment on the radio telephone, listening, commenting, directing.

> When he wasn't on a circuit to someone, he was huddled with his staff or other generals.[17]

Things were no different, nor communications less critical, for Army generals as shown by this quote on the situation in VII Corps,

> The reality of rapid tempo desert operations is the capacity to move faster than the communications reach. ... In fact, ... the VII Corps Commander's personal C3 'vehicle' was a UH-60 Blackhawk[18] ...with a sophisticated communications console.[19]

A typical command post or mobile command and control vehicle that would likely be found today at the operational corps level might traditionally address each area as follows:

(a) **Position/Location** - The commander/staff would determine its own position/location by first narrowing its location to a specific map sheet by reference to a known area of operations and a general location. Specific location would then be determined by terrain association and map reading skills using the lensatic compass. This location is normally plotted on a map or an overlay. The same procedure would be followed at all elements and locations then exchanged by communications using radios, telephones, or by exchanges of overlays and/or written lists. The process is, at best, time consuming, burdensome on communications, difficult to keep current, and prone to error. Unit locations are also often recorded by grid coordinates on charts and sometimes in computer databases. Locations of barriers, obstacles, main supply routes, contaminated areas, ammunition dumps, fuel points, etc. are usually distributed on

overlays with a written operations plan or order and sometimes by voice communications. Misalignment on overlays and copying errors often result in units, boundaries, and other map graphics "migrating" from headquarters to headquarters. Use of computer-generated-and-distributed map reference and overlay data can help alleviate this problem.

Units with GPS avoid the problem of determining their own location since they get a very accurate, direct readout; but, the problems of reporting, posting, updating, and distribution remain. During Desert Shield/Desert Storm GPS was a winner. The DoD report to Congress said, "Use of space-based navigation and positioning was an unqualified success. The NAVSTAR Global Positioning System (GPS) played an important role in the success of the overall operation.".[20] During the conflict 4,490 commercial and 842 military GPS receivers were deployed and provided continuous, all-weather 25 meter accuracy for the commercial small lightweight GPS receiver (SLGR) and 16 meters accuracy for the military model. The heavy reliance on commercial receivers demonstrates the system's only shortcomings: supply not being able to keep up with demand and the need for more military systems. The resounding success of GPS is reflected in the DoD report recommendation that GPS should be considered for incorporation into all weapon systems and platforms.[21]

(b) **Status** - Status of personnel, equipment, weapons systems, and supplies are almost universally reported over voice

communications or by written reports delivered by couriers or liaison personnel. The data is usually transferred to charts or graphs and consolidated at each successive headquarters. Like position/map graphics, keeping status current requires frequent reporting and is manpower and communications intensive.

The problems of status reporting during Desert Shield/Desert Storm are captured in these comments from the officer in charge (OIC) of the VII Corps tactical command post (TAC),

> The Commander's SITREP [situation report], due four times daily. ...While its thirty to forty lines of information are necessary to track Corps combat power status, it is simply unmanageable to expect it accurately every six hours in hard copy in a mobile combat operation.[22]

He attributed the problem to incompatibility of facsimile equipment, lack of reporting discipline, and submission of complete reports that overburdened the communications systems .pawhen only critical changes were needed. His recommended solutions were:

> Corps C3 requires environmentally durable facsimile equipment, adaptable to multichannel TACSAT [tactical satellite] communications..., and, ...An abbreviated combat power SITREP should be routinely used to report major weapon systems availability, conducive to FM or single channel TACSAT reporting, with the other combat power ingredients reported by exception, i.e., when there are significant problems which impact on mission accomplishment.[23]

These recommendations suggest that procedures, as well as the technical means, to handle the flood of information at the operational level are important.

The Maneuver Control System (MCS), and other computer systems, can help in expediting the status reporting process and its limited use in the gulf war provided some insight into its potential. An Army Training and Doctrine Command (TRADOC) after action review concluded that the 270 MCS devices used by units deployed to Desert Shield/Desert Storm were very successful. MCS provided a common friendly and enemy picture of the battlefield and demonstrated that non-developmental hardware functioned well despite the harsh environment. It further pointed out that communications availability and connectivity were critical to MCS use.[24]

(c) **Mission/Situation** - Mission/Situation is normally updated and maintained by the issuance of written plans, "frag" orders, or operations orders. These are usually distributed by couriers or liaison officers. Brevity is achieved by the use of SOPs and local "battle books". Current operational and tactical situations are usually reported by voice communications. Enemy situations are included in the above written documents, in special written intelligence summaries, and by voice. Computer databases are sometimes used to provide a "boiler plate" framework to aid in development of orders and to insure that all required elements are considered and/or covered. In some limited cases orders are transmitted by modem from computer to computer. The MCS system can transfer operations orders and operational situational data via the MSE switching system and is being

upgraded to interface with SINCGARS to allow information dissemination via radio.[25]

(d) **Equipment Capabilities/Requirements** - The technical capabilities of friendly and enemy equipment and order of battle are almost exclusively gleaned from technical manuals, intelligence books, or "fact" books. Some computer databases are available for enemy equipment but are not widely distributed, mainly due to security classification. Where computers have been used they have been very beneficial.

Commanders and their staffs have applied currently available equipment and resources to meet the "generic" information needs of the operational commander in many innovative ways. A Desert Shield/Desert Storm example was VII Corps, "welding Mobile Subscriber Element(sic) (MSE) crank-up antenna bases onto the side of tracked vehicles to provide a relatively stable antenna .pabase 30-40 ft up in the air while driving" to extend FM reach to the 40-50 km range required on command net radios.[26]

As previously discussed, one of the major difficulties has been the lack of an "integrated" communications and computer package to support a command and control vehicle leveraging the capabilities of current and future systems to enhance operational agility. This analysis certainly doesn't address every information need nor every equipment/resource that can be applied. However, it is a plausible and very prevalent solution constrained by the reality of what is available today. Conceptually the communications should be fully automated and

integrated to provide the commander with information and graphic displays that provide the critical data necessary for decisions, synchronization, and planning.[27] What new capabilities can modifications of current systems, procurement of off-the-shelf equipment, or new development provide? The next section addresses these questions.

LEVERAGING EMERGING TECHNOLOGIES FOR NEW CAPABILITIES

New capabilities can be gained from modifications to current equipment (both military and commercial), procurement of off-the-shelf equipment with new capabilities, or by development of new technologies. Since new development is normally expensive the current fiscal realities encourage modifications and off-the-shelf procurement which are normally cheaper. The only new developments may be the software required to integrate the various digital processors and engineering changes to current, or soon to be fielded, equipment. This author maintains that we can improve C4I for the Warrior in the near-term with this approach. Specific modifications recommended and the capabilities they will provide to meet the information and command and control needs of the operational commander are:

(a) **GPS** - For the near-term modify GPS to provide digital output of location and time in a standard data format through a standard RS-232 computer port. This will allow the data to be easily shared among radios, COMSEC devices, and the various computers and digital devices of the common hardware/software

(CHS) program and the Maneuver Control System. GPS should be integrated into the basic system components in the future.

(b) **Combat Net Radio (CNR) and MSRT** - Modify the SINCGARS, UHF TACSAT, and MSRT radios to read the time from the GPS and use it to update their internal time (time is very critical to frequency hopping radios like SINCGARS that now require all operators within the same net to manually enter a time accurate within 4 seconds throughout the net in order to operate).[28] It is absolutely imperative that the SINCGARS FM radio be fielded as soon as possible. During Desert Shield/Desert Storm the older VRC-12 radios broke down every 200 hours, on average, and SINCGARS every 7000 hours while demonstrating a range of 35 miles vice the 10-12 mile range of the VRC-12.[29] A Los Angeles Times report provided these insights into the problems with our radios.

> In interviews across the war zone, commanders made it clear that the U. S. military must find a radio that works. A senior Army official in Washington, asked about complaints that radios were a constant problem responded simply, "Guilty as charged. Our modernization program is late."
>
> ...Lt. Gen. Boomer, the Marine commander, at one point became so frustrated with his inability to communicate that he threw a receiver down in frustration.
>
> "I lose patience during the battle with radios." the chagrined general said in an interview later. But he and others said the frustration of the war made clear the need to replace tactical radio systems that require constant "struggling and fussing."
>
> "It was not a war stopper." Boomer said. "But it was one of those things we'll want to look at."[30]

Secondly, modify the COMSEC device, whether external or embedded in the radio, to read the position from the GPS, to

accept manual keypad input of a unique unit identification code (ID) (like the unit callsign from the SOI), and to accept and transmit data from a computer. Modify the COMSEC data stream to incorporate the location, time, and ID data on transmission and to output the data to a computer port on the receive side. This will allow automatic, accurate updates of unit locations and the time of the last reported location on any computer in the net with every radio transmission. Locations and unit symbols would also be "posted" to computer maps by database management software that will be specifically discussed later.

Another problem associated with combat net radios and COMSEC devices is the need for communications-electronics operations instructions (CEOIs) which contain callsigns and frequencies. These CEOIs are currently centrally produced in a paper format by the National Security Agency. For most operations, including Desert Shield/Desert Storm, a Commander in Chief (CINC) will actually need a joint CEOI (JCEOI). The sheer volume of paper required for such a large theater CEOI and its distribution on the dispersed battlefield were a problem during the war.[31] Recognizing this problem the Chairman, Joint Chiefs of Staff has approved transition from the paper based JCEOI to a fully electronic capability. Implementation requires adoption of the Revised Battlefield Electronic CEOI System (RBECS) software, for local production of CEOIs on an International Business Machines (IBM) compatible computer.[32] Additionally, fielding of the Data Transfer Device (DCD) is required to complete the objective

system and allow a totally paperless environment.[33] Expediting this program is highly recommended.

(c) **MSE** - Complete total Army fielding of MSE incorporating the packet switch overlay to accommodate the increasing need for data transmissions. As discussed above, interface the MSRT with GPS. Lastly, insure interface compatibility with common hardware/software and fax/modem protocols and data compression and error correction techniques.

(d) **MCS and/or CHS computers** - Modify MCS and/or the standard CHS computers to incorporate the following:

(1) A data input/output (I/O) device to interface either type of computer with GPS, the combat net radios (CNRs), and MSRT. This will allow each computer to read its own position and time from the GPS and to receive another unit's identification (ID), position, and report time from the CNRs and MSRT. To allow efficient, rapid transfer of computer databases and files the interface must connect to a radio modem such as the Adaptive Programmable Interface Unit (APIU) currently under development for the MCS program[34] or the Tactical Communications Interface Module (TCIM) available through the second phase of the CHS program.[35] The specific interface is unimportant. What is important is the functionality to allow the computer to pass secure data over any available radio system.

(2) A removable hard drive to facilitate data backup, data transportability, drive replacement, and multiple user databases. A removable, rather than a fixed, hard drive is important for the

reasons cited above as well as for the more important problem of security. With a removable hard drive the computer could be used to process any level of classified information but would be unclassified when the drive was removed. Thus security requirements for a system installed in an unattended location or vehicle would only require normal physical security and not the security required for classified information.

(3) A fax/modem card using industry standard data compression and transmission protocols. This could be external to the computer, and included in the APIC or TCIM discussed previously in paragraph (1), or internal to the computer. The important consideration is to have a facsimile capability adaptable to both military and commercial systems. As previously noted, this need was identified by VII Corps as a critical need during Desert Shield/Desert Storm.

(4) A multimedia Compact Disc, Read Only Memory (CD ROM) drive - To provide access to large databases. CD ROM products are used today within the intelligence community, primarily for mapping and terrain elevation data, but their expanded use has an extremely high payoff and should be vigorously pursued. Because of the widespread interest in the tremendous potential of this technology the second phase of the CHS program includes a CD ROM drive.[36] However, critical to the utility of this device is the production of databases for maps, map symbols, maneuver graphics, friendly and enemy equipment capabilities, technical manuals,

standard forms, standard reports, etc. Research and funding should be directed toward this effort.

The capability to display photographs in the new CD ROM format might be very beneficial, especially for file photos of areas or items of interest within the theater that are primarily static. The multimedia function could also be used to import and display video images from video cameras and observation platforms like remotely piloted vehicles. This might help solve some of the intelligence problems at the operational level. Additionally, efficient use of CD ROM products could almost eliminate the need for paper manuals and stocks of maps.

(5) A trackball, or similar pointing device, to allow use of graphical user interface software to increase operator productivity.

(6) A high definition color monitor. Primarily for display of maps, overlays, digital photographs, and multimedia products (like training subjects or terrain perspective products). Color is important because it enhances, at a glance, the immediate comprehension of the display, such as the red/amber/green representation of unit combat power status, and aids in overall battlefield situational awareness.

(7) A local area network interface. To allow computers in a larger headquarters, or in the separate vehicles of a mobile headquarters at a halt, to share a common interactive database for information and concurrent plans/orders preparation. In the

near-term this would likely be wire or fiber optic cables but ideally would evolve into a wireless system.

(8) A standby power mode that powers the CPU, display and RAM but shuts down the hard drives, floppies, and CD ROM to protect them during mobile operations. This standby mode will allow continuous automatic receipt and update of information from the vehicle radios and posting to the display without operator input.

(9) A combination printer/scanner/copier. Systems are currently available commercially (called "hydra" or "multifunction" printers) that combine these functions. One manufacturer adds a built-in facsimile capability[37] and another provides the three basic functions with a color printing capability.[38] This device could merge maneuver graphics, unit locations, and CD ROM maps to produce color overlays in accurately reproducible, multiple copies. It would also allow paper maps, graphics, and photographs to be scanned into the computer and distributed by removable hard drive, disk, or modem. In addition, it would produce near laser-quality faxes on plain paper and help satisfy the almost insatiable demand in every headquarters for copy capability.

The multifunctionality of these "hydra" devices and their space saving aspects coupled with increased document handling convenience and efficiency have an obvious advantage over separate devices, especially in the limited space of a command and control vehicle. The CHS program should make these devices

available as a component since they can add so much to many system configurations and give commanders much needed flexibility and a tremendous new capability.

(10) Software - The glue that ties all these systems together and provides the integration necessary to make the battlefield interoperable in a seamless communications architecture is the software driving all the computers and digital devices. Proprietary systems, like MCS and most of the stove-pipe systems supporting the battlefield operating systems, must give way to open architecture and multiple-use software. The CHS program's pursuit of common applications like a Briefing System Generator (BSG) to merge map displays with unit symbols and overlay graphics is an example. The fact that this application is based on conversion of a briefing aid program from the Standard Theater Army Command and Control System (STACCS) makes it an even more outstanding example of a better way of doing business today and in the future.[39]

Another software application that would be of great benefit and could help to address the Desert Shield/Desert Storm intelligence problem with imagery dissemination[40] would be software for processing digital photographs in a data compressed format. The utility of this technique was very successfully demonstrated by the 6th Infantry Division (Light) during the Ulchi Focus Lens joint exercise and the III Corps Battle Commander Training Program (BCTP) exercise during 1991. Photographs taken by a hand-held digital camera were compressed

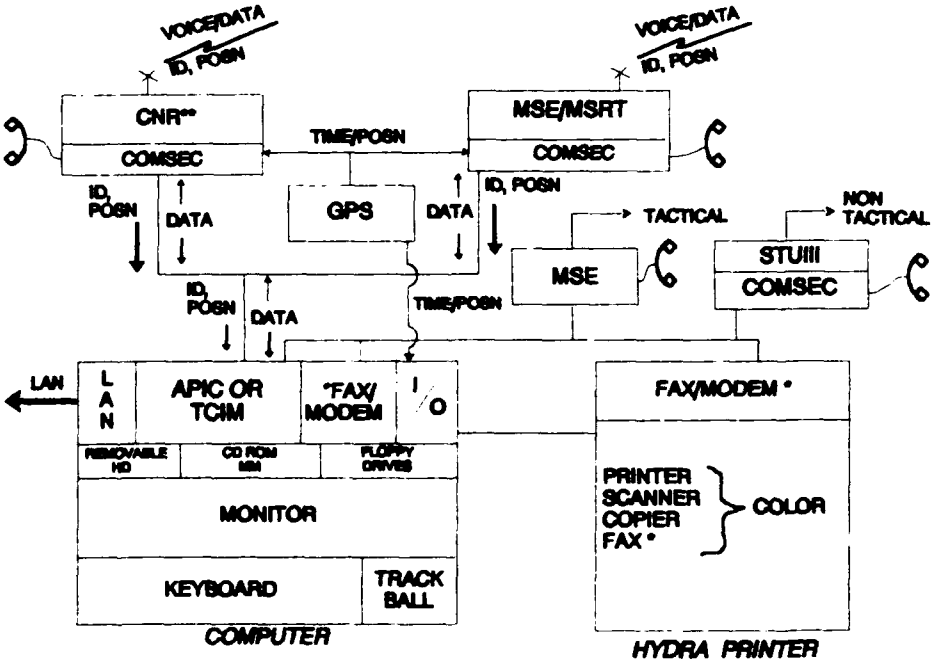
and transmitted from Korea and Ft Hood, respectively, using tactical communications systems, the Alaskan Command computer network called Command Tactical Information System (CTIS), and leased commercial satellites. With a 20 to 1 compression the photos were transmitted quickly and readily viewed on local computers in the CTIS network.[41]

The next step is to put this all together and see what it gives the operational commander in a command and control vehicle or mobile command post.

PUTTING IT TOGETHER, A NEAR-TERM C4I SOLUTION

A recommended communications and computer workstation for a mobile command and control vehicle (C2V) is shown below.

C2 VEHICLE COMMUNICATIONS AND COMPUTER SUITE



*FAX/MODEM required for computer, optional for printer/scanner/copier.

**Number and type of Combat Net Radios determined by MISSION/headquarters

FIGURE 1

Note that the equipment in the upper part of the diagram; Combat Net Radio (CNR), MSRT, GPS, STU-III and MSE; are items that are currently, or soon to be, fielded and likely to be already available at a corps tactical headquarters or installed in a command vehicle.

To function as shown they will require the modifications described in the previous section. The computer and hydra printer are the only non-military equipment. However, they can, and definitely should, be made available through the common hardware/software program. How then do they work together in this configuration?

(a) The GPS provides position and time to the CNR, MSRT, and computer. The time updates the internal clocks of the CNR, MSRT, and computer. The position updates the computer database and is transmitted with the user ID and report time whenever the CNR or MSRT is keyed.

(b) The CNR and MSRT operate normally with the exception that they transmit their own ID, position, and time with the COMSEC synchronization signal on every transmission. They also receive the same information from other radios in the net and pass it to the computer where the resident software automatically updates the database and posts any changes to the display currently in use.

(c) The MSE telephone must be the data-capable model to allow interface with the computer for file transfers into the MSE

packet switch network. Likewise the STU-III must be data-capable but, otherwise, both operate normally.

(d) The computer is the heart of the system. It maintains multiple databases for status reports and manages the inputs and outputs from all the other devices. It also receives the unit ID data and automatically converts it to the proper unit symbology and posts it to any map displays. If configured to run with an application like Windows it could provide multiple displays, particularly on a larger monitor.

(e) The hydra printer acts as a color printer, scanner, and copier. It might also have a built-in facsimile capability that could operate independently of the computer. It can print maps from the CD ROM or composite maps, digital photographs, graphics etc. from the computer. It can scan paper maps, diagrams, hand-written notes, and documents for use or transmission. And, it can act as a local copier.

This is the system. Since all the equipment is either military standard or available through the common hardware/software (CHS) program maintenance should be through normal logistics channels. However, this is not easy. Currently the Army has a very limited number of computer repair personnel and specific maintenance concepts for computer repair have not been developed. In fact, logistical support of all the electronics proliferating on the battlefield is a complex subject worthy of study. However, it is beyond the scope of this paper. With this limitation in mind we now need to see if we have met

the objective of improving the near-term C4I for the Warrior at the operational level.

CONCLUSIONS

The focus of this study is reflected in the comments of the OIC for the VII Corps TAC during Desert Shield/Desert Storm. His bottom line assessment of command and control was,

> ... the weak link in our current and projected C3 systems at the Corps level and lower is in communications and command post vehicle systems. ...Synchronization of the battle places a premium on the C3 Battlefield Operating System.[42]

This study has put forth recommendations to address identified shortcomings from Desert Shield/Desert Storm like the assessment above. The proposed communications and computer suite workstation for a C2 vehicle can satisfy almost all the information needs of the operational commander with minor modifications to current equipment and thoughtful integration of available off-the-shelf automation. It is consistent with the C4I for the Warrior program and provides recommendations for consideration in the Quick Fix and Mid-Term phases. It certainly reduces, but doesn't eliminate, the need for large volumes of reference materials, map inventories, and wall charts.

The continuing challenges are to change the way we display, use, and communicate information and to change our current development strategy of "stovepipe" systems. The Army and DoD must think common hardware/software integration

leveraging private industry developments and the exploding technologies. Additionally, both the Army and DoD must determine how they are going to logistically support the new C4I systems.

In the final analysis, we should use the lessons learned from Desert Shield/Desert Storm to enhance our combat capability as a nation. As the Army Chief of Staff, General Sullivan, said, "... in order to maintain our significant capability edge we must learn the right lessons from our recent operations and use them to upgrade our doctrine.".[43] I'm sure he would say the same about our C4I systems. We can provide command and control support to the operational commander better, quicker, and probably cheaper by pursuing equipment modifications and off-the-shelf procurement. The real question is, Will we?

ENDNOTES

[1]Department of Defense, Conduct of the Persian Gulf War, Final Report to Congress (Washington: U. S. Department of Defense, April 1992), 236.

[2]David D. McKiernan, Command, Control, and Communications at the VII Corps Tactical Command Post: Operation Desert Shield/Desert Storm (Carlisle Barracks, PA: U. S. Army War College, 15 April 1992), 13.

[3]Joint Chiefs of Staff, C4I for the Warrior (Washington: J-6 the Joint Staff, 12 June 1992), 1.

[4]Ibid., 16-17.

[5]Paul F. Roques Jr., Operational Decisions and the Information Explosion! What are the Critical Joint Warfighting Requirements for the CINC? (Carlisle Barracks, PA: U. S. Army War College, 31 March 1989), 1.

[6]Frederick J. Kroesen, "What Should a Command Post Do?," Army 43, No 1 (January 1993): 33.

[7]Ibid., 34.

[8]Wilson A. Shoffner, Command and Control (Ft Leavenworth, KS: Briefing, U. S. Army Combined Arms Command, June 1992), 3.

[9]Department of the Army, Decade of Change - Challenge for the 1990's (Ft Monroe, VA: Briefing, U. S. Army Training and Doctrine Command, n. d.), 35.

[10]Robert H. Williams, "Satellites Manage Future Battlefields," Signal 47, No 5 (January 1993): 60.

[11]Kroesen, 32.

[12]Richard P. Tracy and Raymond Herrick, "Battlefield Communications Adds Capability, Flexibility," Signal 47, No 6 (February 1993): 45.

[13]Don Rickerson and John Hinman, "MSE's Mobile Subscriber Radio Telephone Subsystem," Army Communicator 17, No 1 (Spring 1992): 8.

[14]Secretary of Defense Dick Cheney, Annual Report to the President and the Congress (Washington: U. S. Department of Defense, January 1993), 32.

[15]Stephen Larsen, "Giving Commanders Tomorrow's System Today," Army Communicator 16, No 3 (Summer 1991): 48-50.

[16]Department of Defense, Conduct of the Persian Gulf War, Final Report to Congress, 806.

[17]Molly Moore, "Storming the Desert With the Generals," Washington Post, 14 April 1991, sec. B, p. 4.

[18]McKiernan, 45.

[19]McKiernan, 13.

[20]Department of Defense, Conduct of the Persian Gulf War, Final Report to Congress, 569.

[21]Ibid., 807.

[22]McKiernan, 32.

[23]Ibid., 33.

[24]Department of the Army, Decade of Change - Challenge for the 1990's, 35.

[25]Larsen, 50.

[26]McKiernan, 42.

[27]John C. Eberle, "Command and Control Vehicle Working Draft Operations Concept Staffing," memorandum, Ft Leavenworth, KS, 14 January 1993, 9.

[28]Kenneth C. App, Evaluation of SINCGARS Capability and Interoperability with Respect to the Navy and Marine Corps (Carlisle Barracks, PA: U. S. Army War College, 28 March 1988), 4.

[29]Douglas Jehl and Tracy Wilkerson, "Looking for Lessons: U. S. Evaluates Tactics, Weapons of Gulf War," Los Angeles Times, 24 March 1991, sec. A, p. 1.

[30]Ibid., 3.

[31]Department of Defense, Conduct of the Persian Gulf War, Final Report to Congress, 571.

[32]R. C. Randt, Revised Battlefield Electronic CEOI System (RBECS) Application Utility Package, Documentation, Version 2.4 (Ft Meade, MD: National Security Agency, January 1993), 1.

[33]R. C. Macke, "Joint Communications-Electronics Operation Instructions," memorandum, Washington, 16 July 1992, 1-2.

[34]MILTOPE Corporation, Common Hardware/Software ...CHS, Product Guide (Melville, NY: n. p., n. d.), 8.

[35]Science Applications International Corporation (SAIC), Lightweight Computer Unit (n. p., 1991), 5.

[36]Ibid., 7.

[37]Bruce Brown, "Print, Fax, Copy, and Scan with Okidata's All-In-One DOC-IT," PC Magazine 12, No 4 (February 23, 1993): 37.

[38]Canon, Inc., "Get the Power (advertisement)," PC Magazine 11, No 19 (November 10, 1992): 231.

[39]Walter L. Olson, "Weekly Status Report for Common Hardware/Software," Memorandum for Program Executive Officer, Command and Control Systems, Ft Gordon, GA, 29 January 1993, 2.

[40]Department of Defense, Conduct of the Persian Gulf War, Final Report to Congress, 342.

[41]Personal experience of the author while assigned as the Division Signal Officer, June 1990 - June 1992.

[42]McKiernan, 61-62.

[43]Gordon R. Sullivan, "The Army's Strategic Issues," Letter to the Army (Washington: 19 July 1991), 1.

BIBLIOGRAPHY

App, Kenneth G. Evaluation of SINCGARS Capability and Interoperability with Respect to the Navy and Marine Corps. Carlisle Barracks, PA: U. S. Army War College, 28 March 1988.

Army Communicator 17, No 1 (Spring 1992): 56-59, s. v. "TSM Corner."

Brown, Bruce. "Print, Fax, Copy, and Scan with Okidata's All-In-One DOC-IT." PC Magazine 12, No 4 (February 23, 1993): 37-39.

Campbell, Robert W., COL, USA. "System Integration Plan." Memorandom for PM, SINCGARS. Ft Gordon, GA, 4 December 1992.

Campen, Alan D., COL, USAF(Ret). "Defense Centralizes Controls Over Imagery, Information Systems." Signal 47, No 5 (January 1993): 61-82.

Canon, Inc. "Get The Power" (Advertisement) PC Magazine 11, No 19 (November 10, 1992): 231.

Cheney, Dick, Secretary of Defense. Annual Report to the President and the Congress. Washington: U. S. Department of Defense, January 1993.

Clark, Wesley K., MG, USA. Concepts and Doctrine for the Future Battlefield. Briefing, place unknown: n. d.

Dyer, Herbert D. Joint Tactical Command, Control and Communications (C3) Interoperability. Carlisle Barracks, PA: U. S. Army War College, 12 March 1990.

Eberle, John C., COL, USA. "Command and Control Vehicle Working Draft Operations Concept Staffing." Battle Command Battle Laboratory Memorandum. Ft Leavenworth, KS, 14 January 1993.

ITT Aerospace/Optical Division. SINCGARS System Document, A Description of the Ground Radio Subsystems, Revision C. 10 January 1986.

Jehl, Douglas and Tracy Wilkinson. "Looking for Lessons: U. S. Evaluates Tactics, Weapons of Gulf War." Los Angeles Times, 24 March 1991, sec 1A. p. 1.

Joint Chiefs of Staff. C4I for the Warrior, Pamphlet, C4 Architecture & Integration Division (J6I). Washington, 12 June 1992.

Joint Chiefs of Staff. Doctrine for Command, Control, and Communications Systems Support to Joint Operations, Test Pub, Joint Publication 6-0. Washington, 12 June 1990.

Jones, Donald L. "Evaluation of JCEOI in Exercise COBRA GOLD 92" Enclosure to R. M. Macke, VADM, USN, Memorandum, "Joint Communications-Electronics Operations Instructions." Joint Staff Memorandum J-6A 01085-92. Washington, 16 July 1992.

Kroesen, Frederick J., GEN, USA(Ret). "What Should a Command Post Do?" Army 43, No 1 (January 1993): 32-35.

Larsen, Stephen. "Giving Commanders Tomorrow's System Today." Army Communicator 16, No 3 (Summer 1991): 48-50.

Macke, R. C., VADM, USN. "Joint Communications-Electronics Operation Instructions." Joint Staff Memorandum J-6A 01085-92. Washington, 16 July 1992.

Matthews, William. "Schwartzkopf names key U. S. weaknesses." Army Times, 24 June 1991, p14.

McKiernan, David D. Command, Control, and Communications at the VII Corps Tactical Command Post: Operation Desert Shield/ Desert Storm. Carlisle Barracks, PA: U. S. Army War College, 15 April 1992.

MILTOPE Corporation. Common Hardware/Software ... CHS, Product Guide. Melville, NY: n. d.

Moore, Molly. "Storming the Desert With the Generals." Washington Post, 14 April 1991, sec B, p1, 4-5.

Mundie, William L. Jr. Command, Control, and Communications Lessons Learned in Division Command. Carlisle Barracks, PA: U. S. Army War College, 15 April 1992.

National Defense University, The Joint Staff Officers Guide 1991 Armed Forces Staff College Pub 1, Norfolk, VA, 1991.

National Research Council. STAR 21, Strategic Technologies for the Army of the Twenty-First Century. Washington: National Academy Press, 1992.

Olson, Walter L., COL, USA. "Weekly Status Report for Common Hardware/Software." Memorandum for Program Executive Office, Command and Control Systems. Ft Gordon, GA, 29 January 1993.

Randt, R. C., Revised Battlefield Electronic CEOI System (RBECS) Application Utility Package, Documentation, Version 2.4, National Security Agency, V27. Ft Meade, MD, January 1993.

Rickerson, Don, CPT, USA and John Hinman. "MSE's Mobile Subscriber Radio Telephone Subsystem." Army Communicator 17, No 1 (Spring 1992): 6-16.

Roques, Paul F. Jr. Operational Decisions and the Information Explosion! What Are the Critical Joint Warfighting Requirements for the CINC?. Carlisle Barracks, PA: U. S. Army War College, 31 March 1989.

Science Applications International Corporation (SAIC). Lightweight Computer Unit (Product Brochure). n. p., 1991.

Shoffner, Wilson A., LTG, USA. Command and Control. Briefing presented at the Command Arms Center, U. S. Army Combined Arms Command, Ft Leavenworth, KS: June 1992.

Shore, David. "Computer Technology Stands Poised for Substantial Leap." Signal 47, No 6 (February 1993): 35-37.

Sullivan, Gordon R., GEN, USA, "The Army's Strategic Issues." Letter to the Army, Washington, 19 July 1991.

Tracy, Richard P. and Raymond Herrick. "Battlefield Communica tions Adds Capability, Flexibility." Signal 47, No 6 (February 1993): 45-47.

U. S. Department of Defense. Conduct of the Persian Gulf War, Final Report to Congress. Washington: U. S. Department of Defense, April 1992.

U. S. Department of the Army. CORPS Operations. Field Manual 100-15. Washington: U. S. Department of the Army, September 1989.

U. S. Department of the Army. Desert Storm Special Study Project. General Officer Steering Committee for Desert Shield/Desert Storm Lessons Learned. Briefing. (place unknown): 17 September 1991.

U. S. Department of the Army, Project Manager Single Channel Ground and Airborne Radio System. Single Channel Ground & Airborne Radio - SINCGARS. Overview briefing. Ft Monmouth, NJ: 30 December 1992.

U. S. Department of the Army, U. S. Army Communications Electronics Command (CECOM). Single Channel Ground and Airborne Radio System (SINCGARS) Test and Evaluation Master Plan (TEMP). Ft Monmouth, NJ: 30 December 1987.

U. S. Department of the Army, U. S. Army Military History Institute, Division Commanders' Lessons Learned (DCLL) Program: Experiences in Division Command. Carlisle Barracks, PA: 1990. 18-21.

U. S. Department of the Army, U. S. Army Signal Center. TRADOC System Manager, Multifunctional Computer (TSM-MFC). Office Overview Briefing. Ft Gordon, GA: 2 February 1993.

U. S. Department of the Army, U. S. Army Space Technology and Research Office. Army Science and Technology Master Plans for Space (ASTMPS), Coordinating Draft. Washington: 14 October 1992.

U. S. Department of the Army, U. S. Army Training and Doctrine Command.Decade of Change - Challenge for the 1990's. Briefing presented at Ft Monroe, VA: n. d.

U. S. Department of the Army, U. S. Army Training and Doctrine Command. Desert Storm Conference, Carrying the Lessons Forward. Briefing presented at Ft Monroe, VA: 2-3 March 1992.

Van Creveld, Martin. Command in War. Cambridge, MA, Harvard University Press, 1985.

Williams, Robert H. "Satellites Manage Future Battlefields." Signal 47, No 5 (January 1993): 58-60.

Yeosock, John J., LTG, USA. Commander U. S. Army Central Command (USARCENT). Operation Desert Storm. Briefing. Ft McPherson, GA: 15 August 1991.